



Bioscience Biofuels

Unlocking the Keys to Next-Generation Biofuels: Advanced Pretreatment Technology

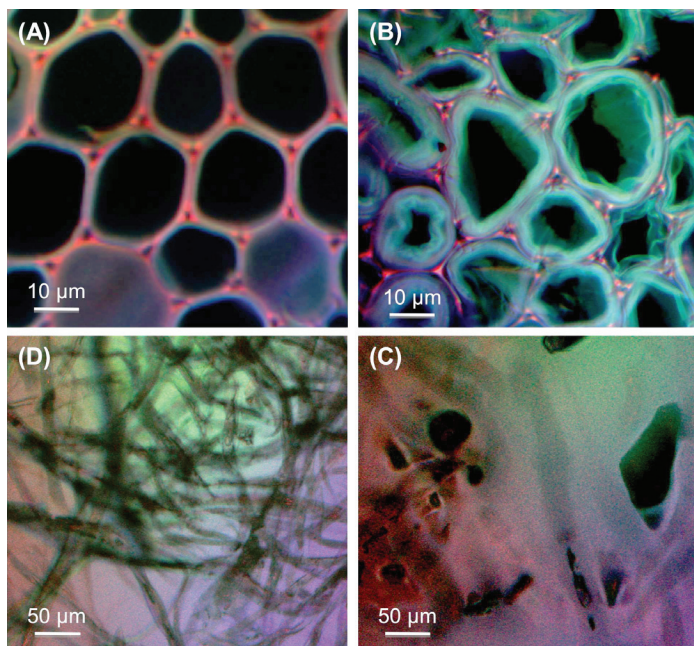


Figure 1: Confocal fluorescence images of switchgrass cell wall, (A) before pretreatment and (B) swollen cell wall after 10 min pretreatment with ethyl methyl imidazolium acetate at 1208 °C. Highly-polar ionic liquids are very effective in solvating cellulosic biomasses due to hydrogen bond formation between hydroxyl group hydrogen atoms in the cellulose and ionic liquid anions. (C): *In situ* examination three hours after pretreatment. Confocal optical slice showing cellulose regeneration after anti-solvent (water) addition into ionic liquid-solubilized switchgrass. (D): Product recovery. Regenerated non-fluorescent cellulose appears to reject lignin and appear as dark fibers in the lignin–ionic liquid fluorescent solution.

*As a partner in the Joint
BioEnergy Institute,
Sandia is working to
advance the technology
of efficient biofuel
production.*

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Transportation fuels are the largest end use of energy by sector in the U.S. A full two-thirds of the world's petroleum resources are used for transportation, and 60% of that is used for ground transportation. Petroleum production is predicted by many experts to peak within ten to thirty years, after which time worldwide production will decline until resources are exhausted, resulting in dramatically higher fuel costs and potentially disastrous geopolitical conflicts for resources. What's more, each gallon of gasoline and diesel produces an astonishing twenty pounds of CO₂ (resulting in an average of seven tons per vehicle per year); thus the millions of vehicles used globally are contributing significantly to climate change.

As liquid fuels derived from solar energy and carbon stored in renewable plant biomass, biofuels are becoming increasingly important alternatives to petroleum.

Recently, the Department of Energy's Office of Science established Bioenergy Research Centers to advance the development of the next generation of biofuels. One such center, the Joint BioEnergy Institute (JBEI), is a San Francisco Bay Area partnership that is led by Lawrence Berkeley National Laboratory and includes Sandia, the University of California campuses of Berkeley and Davis, the Carnegie Institution for Science, and Lawrence Livermore National Laboratory. JBEI's primary scientific mission is to focus on three key areas: feedstock (biomass) production, deconstruction of the feedstock, and fuels synthesis.

Most current pretreatments for enhancing the deconstruction of the lignocellulose component of biomass utilize acids that result in an overall loss of sugars. These acids also yield toxic by-products that inhibit the biofuel fermentation process, again resulting in an overall loss of sugars. Thus successful



commercial production of advanced biofuels will require new pretreatment approaches that enhance cellulose conversion to sugars and minimize the formation of toxic by-products, as well as new enzymes that are capable of efficiently deconstructing both the sugar and lignin components of plant cell walls. Sandia researchers in JBEL's Deconstruction Division are developing better methods to "pretreat" lignocellulose in order to enhance its deconstruction into fermentable sugars. The focus is on the use of ionic liquids, salts that are liquid rather than crystalline close to room temperature. Ionic liquid pretreatments have been proven to significantly enhance the rate of hydrolysis of cellulose, but they require large amounts of antisolvent (a solvent in which the product is insoluble) to recover the amorphous cellulose. Furthermore, a portion of the sugars may be lost to the antisolvent phase, particularly if water is used. Researchers are investigating both the effects of ionic liquids on biomass and the recovery of sugars from the ionic liquid/biomass liquor.

To generate the first published results [1], Sandia researchers used advanced imaging techniques such as confocal fluorescence microscopy to reveal how the ionic liquids interact with and disrupt the plant cell walls of switchgrass (Figure 1). From these images, it is observed that the ionic liquid completely dissolves the plant cell walls of switchgrass and generates a product that is more readily converted into sugar due to decreased lignin content and decreased cellulose crystallinity. These results pave the way for further development of the ionic liquid technology to produce a cheap, robust, and environmentally friendly route of converting biomass into biofuel.

Reference

1. Seema Singh, Blake A. Simmons, and Kenneth P. Vogel, Visualization of Biomass Solubilization and Cellulose Regeneration During Ionic Liquid Pretreatment of Switchgrass, *Biotechnology and Bioengineering*, 104 (2009) 68-75.